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Comparison of Computed Tomography and Routine Radiography of the Tympanic Bullae in the Diagnosis of Otitis Media in the Calf

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Background: Otitis media is difficult to diagnose antemortem. Case reports have described computed tomography (CT) in the diagnosis, but not all cases were confirmed.

Hypothesis: CT is a sensitive and specific imaging modality of the tympanic bullae and can be used as the gold standard for the diagnosis of otitis media.

Animals: Sixteen Holstein calves 5–7 weeks of age were included.

Methods: Prospective study. All calves were sedated with IV xylazine (0.05–0.15 mg/kg) for routine radiography (3 views) and CT of the tympanic bullae followed by necropsy.

Results: Based upon necropsy findings, 10 of 16 calves were affected with otitis media, 4 unilaterally and 6 bilaterally. Imaging changes associated with otitis media included increased soft tissue opacity within the bulla, thickening of the bulla wall, enlarged bulla, and osteolysis of the bulla wall and trabeculations. The most frequent radiographic changes were lysis of trabeculations and increased soft tissue opacity, which were present in 56.3% of affected bullae. On CT, increased soft tissue opacity within the bulla was present in 93.8% of affected bullae. Sensitivity of radiography and CT was 68.8 and 93.8% and specificity was 50 and 100%, respectively. The κ value between radiography and CT with necropsy diagnosis was 0.19 for radiography, indicating poor agreement, and 0.94 for CT, indicating excellent agreement.

Conclusion: CT is more specific, more sensitive, and easier to interpret than radiography and can be used as the gold standard in the diagnosis of otitis media in the calf.

Key words: Bovine; Gold Standard; Kappa; Xylazine.

The diagnosis of otitis media in the calf is based on the presence of appropriate clinical signs such as facial nerve dysfunction, discharge from the external ear, fever, epiphora, and decreased appetite.[1–6] However, many affected calves remain clinically undetected, and bilaterally affected animals may only have clinical signs unilaterally, making accurate antemortem diagnosis difficult.[1,7] Routine radiography and computed tomography (CT) can be useful adjunctive diagnostic tests to confirm the diagnosis.[5,8] Traditionally in small animals, 4 views are recommended for assessment of the tympanic bulla: 20° ventral-laterodorsal oblique of each side, dorsoventral, and 30° open-mouth ventral-caudodorsal oblique.[9] The 30° open-mouth ventral-caudodorsal oblique view is not possible in ruminants as the mouth cannot be physically opened wide enough. Radiographic changes consistent with otitis media in small animals include increased soft tissue opacity within the normally airfilled tympanic bulla, thickening of the bulla wall, change in contour or size of the bulla, and bony proliferation or lysis of the bulla.[8,10,11] Radiographic interpretation of the tympanic bulla is limited by superimposition of the cranial structures and proper positioning of the patient.[9] CT is the preferred diagnostic imaging modality to evaluate bony structures associated with the middle-inner ear in the dog[12] and has been reported to be more sensitive in the diagnosis of otitis media in this species.[13] CT allows imaging of both tympanic bullae simultaneously in transverse sections without the need to reposition the patient. Also, with this imaging modality no superimposition of structures occurs and image contrast is superior to that of radiography.[10] Radiography and CT of the tympanic bullae both require general anesthesia in small animals. CT under general anesthesia has been documented in a few case reports in the diagnosis of otitis in calves but the diagnosis was not confirmed in all cases.[14–17] The validity of these 2 diagnostic imaging modalities in the diagnosis of otitis media has not been reported in cattle. In addition, the imaging abnormalities associated with otitis media have not been described except for individual case reports. This prospective study compares routine radiography and CT of the tympanic bullae using sedation in young calves. The goal of this study is to describe radiographic and CT abnormalities associated with otitis media and to demonstrate that CT can be used as the gold standard for the diagnosis of otitis media in the calf.

Abbreviation:

CT computed tomography

Materials and Methods

Sixteen dairy calves obtained from local producers were included in this prospective study. There were 15 males and 1 female, and all calves were between 5 and 7 weeks of age. They ranged in weight from 38.5 to 56.5 kg. The calves were purchased for an unrelated study and subsequently were recruited for the study of otitis.

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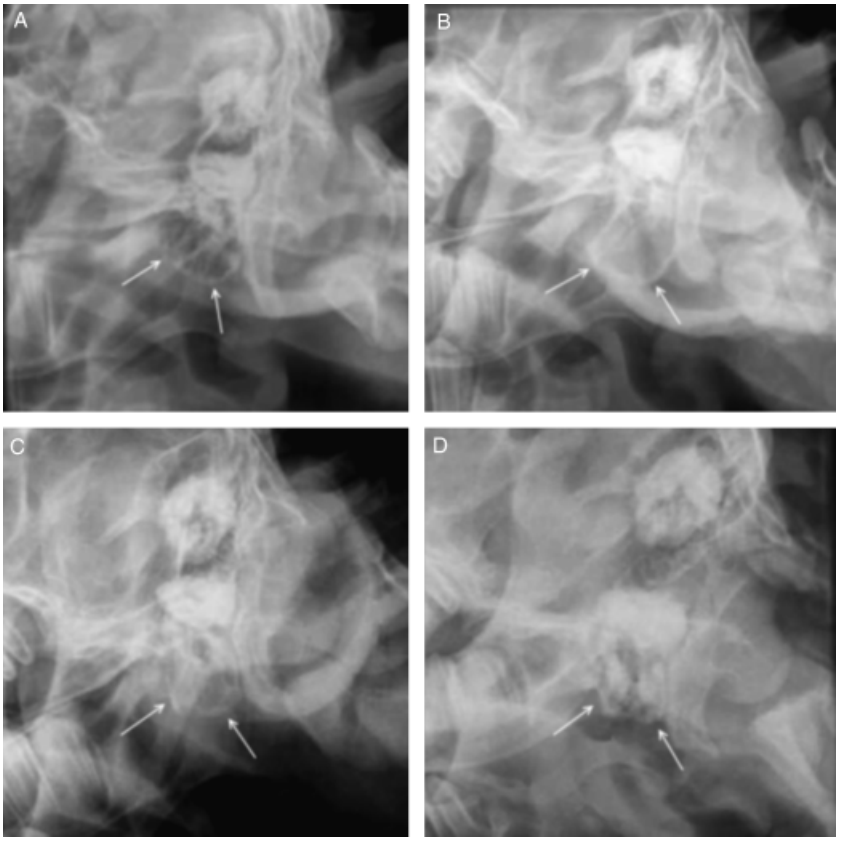

Fig 1. Radiographic images (20° ventral-laterodorsal oblique) of 4 different calves. (**A**) Normal calf demonstrating the presence of bony trabeculations within the normally air-filled bulla. (**B**) Affected calf demonstrating lysis of the bony trabeculations and apparent increased bulla size. (**C**) Affected calf demonstrating lysis of the bony trabeculations and increased soft tissue opacity. (**D**) Normal calf incorrectly identified as affected (false positive) based upon radiographic interpretation of increased soft tissue opacity, lysis of the bony trabeculations, and bulla wall thickening.

The calves had no history or clinical signs of otitis at the time of purchase. They were housed individually in pens at the bovine clinic of the Centre Hospitalier Universitaire Vétérinaire. Calves were sedated with xylazine[a] at a dosage of 0.05–0.15 mg/kg IV for CT and radiographs were taken immediately afterward. Radiographic examination consisted of dorsoventral or ventrodorsal, left 20° ventral-right dorsal oblique and right 20° ventral-left dorsal oblique views using 8–12 mA s and 75 kVp.[b] Non-contrast-enhanced CT for all calves was performed with an on-site, single-detector row, third generation scanner.[c] Contiguous 2 mm transverse slices were obtained at 1 mm intervals from the temporomandibular joints to the caudal margin of the petrous temporal bones. The calves were positioned in sternal recumbency with the hind limbs flexed underneath the body and the head placed in the head support. A self-adhesive belly band was used to secure the body and 1 in. white tape was used to secure the head and hold the front limbs flexed and pulled caudally. CT parameters were 130 kVp, 105 mA, and a 1 second tube rotation time. Images were reconstructed with a bone algorithm; field of view of 20 cm and matrix of 512×512. The calves were euthanized with an IV injection of pentobarbital[d] at a mean of 4 days (range, 0–14 days) after the diagnostic tests. Only 1 calf was necropsied 14 days after diagnostic tests, whereas 8 of 16 calves had a delay of 1 day or less. Necropsy was performed by a board-certified pathologist on the day of euthanasia. The study was approved by the University of Montreal ethical committee for animal use.

Radiographic and CT images of each bulla were evaluated in digital imaging and communications in medicine format on a diagnostic work station[e] by a board-certified radiologist, blinded to the final necropsy diagnosis. Images were evaluated for the presence of increased soft tissue opacity within the bulla, thickened bulla wall, enlarged bulla, and osteolysis of the bulla wall and trabeculations (Figs 1 and 2). Each bulla then was considered unaffected or affected with otitis media based on the previously mentioned criteria. To quantitatively determine if affected bullae were significantly larger than nonaffected bullae, the height and width of each bulla were measured on transverse CT images. To correct for variation in size of calves, height and width ratios were calculated using the stylohyoid bone width on each side as the denominator.

The κ value was calculated for agreement between radiography and CT with necropsy diagnosis. Data regarding bulla height and width were analyzed with a mixed linear model using $P < .05$ to define significance.[f] Sensitivity, specificity, and predictive values for radiography and CT were calculated using necropsy as the gold standard.

Results

Based on necropsy findings, 10 of 16 calves were affected with otitis media, 4 unilaterally and 6 bilaterally, giving a total of 16 of 32 affected bullae. Of the calves affected unilaterally, all were affected on the left side. Based on the gold standard diagnosis by necropsy, radiography correctly identified 11 of 16 affected bullae whereas CT correctly identified 15 of 16 affected bullae.

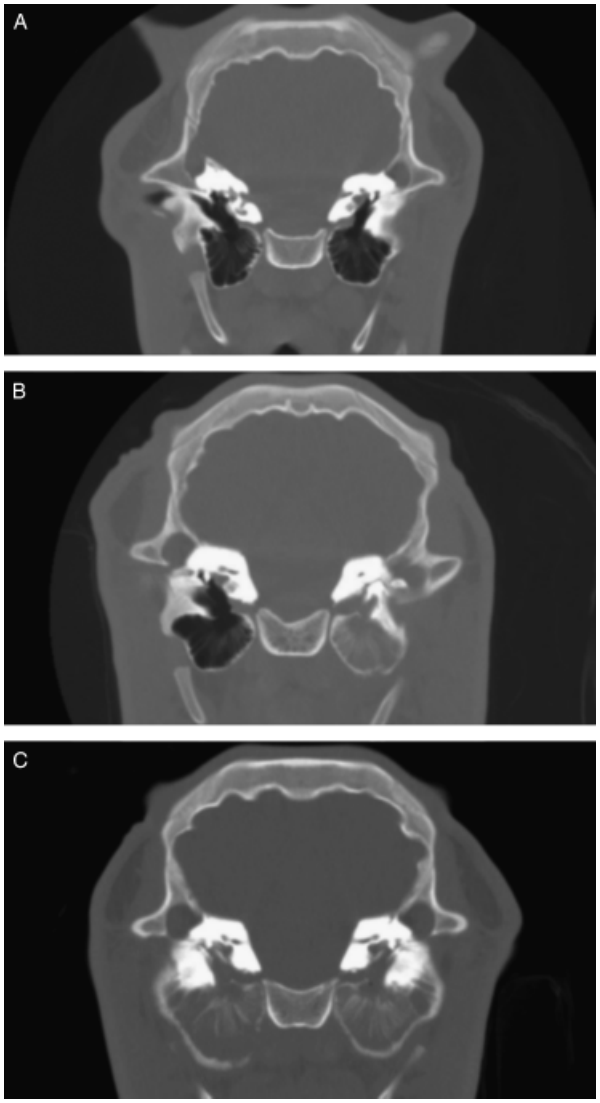

Fig 2. Computed tomography images, bone window, of 3 different calves, right side on the left of the image. (**A**) Normal calf: note the clear definition of the bony trabeculations within each bulla. (**B**) Unilaterally affected calf on the left side demonstrating increased soft tissue opacity within the tympanic bulla. (**C**) Bilaterally affected calf with increased soft tissue opacity, bulla wall lysis, and apparent bulla enlargement.

Radiography incorrectly identified 8 of 16 normal bullae as affected, whereas no false positives were identified on CT. Results are summarized in Table 1. Based on these results, sensitivity ($a/a + b$), specificity ($d/c + d$), positive predictive value ($a/a + c$), and negative predictive value ($d/b + d$) of radiography and CT for the diagnosis of otitis media were calculated and are presented in Table 2. The sensitivity of CT was superior to radiography at 93.8 and 68.8%, respectively. The specificity of CT also was superior to that of radiography at 100 and 50%, respectively. The most frequent radiographic changes consistent with the correct diagnosis of otitis media were lysis of the trabeculations and increased soft tissue opacity within the tympanic bulla, which were present in 56.3% of correctly identified bullae. The most reliable change on CT images consistent with the correct diagnosis of otitis media was increased soft tissue opacity within the bulla, which was present in 93.8% of correctly identified bullae. Table 3 summarizes each imaging parameter and the relative percentages in affected and unaffected animals. Acquisition time for radiographic views ranged from 10 to 20 minutes including film development and repositioning. Acquisition time for CT images was 20–40 seconds after sedating and positioning the animal, which took approximately 5 minutes.

Table 1. Radiographic and computed tomography results of otitis media in 16 calves (32 bullae).

Necropsy Findings	Abnormal (16/32)	Normal (16/32)
Radiographic interpretation		
Otitis	11[a]	8[c]
Normal	5[b]	8[d]
Computed tomography interpretation		
Otitis	15[a]	0[c]
Normal	1[b]	16[d]

[a]True positive.
[b]False negative.
[c]False positive.
[d]True negative.

The κ value to evaluate agreement between radiography and CT with the necropsy diagnosis was calculated based on the final diagnosis of affected bulla with otitis media or normal. The κ value between radiography and necropsy was 0.19, indicating poor agreement, whereas the κ value between CT and necropsy was 0.94, indicating excellent agreement.

There was no statistically significant difference in bulla height, width, height ratio, or width ratio between affected and unaffected bullae. Mean values with corresponding *P* values are presented in Table 4.

Discussion

The radiographic images often were difficult to assess attributable to the superimposition of cranial structures over the tympanic bullae. The procedure also was time consuming, requiring repositioning of the animal to obtain all 3 views. The anatomy of the bovine mandible precludes the open mouth oblique view, which is unfortunate because it is considered the most valuable view in the diagnosis of otitis media in small animals.[9,11] Comparison between sides was difficult when both bullae

Table 2. Sensitivity, specificity, and predictive values of radiography and computed tomography in the diagnosis of otitis media in 16 calves.

	Radiography	Computed Tomography
Sensitivity (%)	68.8	93.8
Specificity (%)	50	100
Positive predictive value (%)	57.9	100
Negative predictive value (%)	61.5	94.1

Table 3. Percentage of radiographic and computed tomographic abnormalities observed in affected/unaffected bullae.

	Radiography (%)	Computed Tomography (%)
Increased fluid opacity within bulla	56.3/18.8	93.8/0
Bulla wall thickening	25/31.3	75/0
Enlargement of the bulla	18.8/6.3	62.5/0
Osteolysis of bulla wall	31.3/25	37.5/0
Osteolysis of trabeculations	56.3/56.3	62.5/0

were mildly affected. Radiographic changes were more prominent when there was extensive bony lysis or marked enlargement of the bulla. Radiographic changes consistent with otitis media in this report included increased soft tissue opacity within the bulla, thickened bulla wall, enlarged bulla, and osteolysis of the bulla wall and trabeculations. The most frequent radiographic changes consistent with the correct diagnosis of otitis media appear to be lysis of the trabeculations and increased soft tissue opacity within the tympanic bulla. These 2 abnormalities were present in 56.3% of bullae correctly identified with otitis media. The presence of increased soft tissue opacity within the bulla may have falsely created the impression of trabeculation lysis and therefore the relevance of this parameter should be evaluated with caution. Tympanic wall thickening and subtle enlargement of the bulla often were difficult to interpret because of the superimposition of cranial structures. A surprising finding was the presence of 50% false positives. It is clear (Table 3) that many radiographic changes were considered present in several unaffected bullae, demonstrating the obvious limitations of this imaging modality. Previous reports in small animals do not mention false positives[10–13]; however, the anatomy of the bovine tympanic bulla is different. The presence of trabeculations within the tympanic bulla in cattle decreases the contrast between the air-filled bulla and bone. The normal trabeculations produce increased opacity within the bulla making assessment difficult. False negatives also were common (27.8%), which is similar to the reported incidence in small animals and in a previous case report of 2 calves.[11,13,14]

In comparison, CT images were easier to assess. The transverse sections allow comparison between sides without superimposition. The procedure was faster compared with radiography because the animal was positioned once. Because of the fast acquisition time, sedation with xylazine alone was sufficient to obtain high-quality images of diagnostic value. The contrast between air and soft tissues by CT was superior to radiography and the tympanic trabeculations were easily observed. In addition, the intracranial structures could be assessed, which was not possible with routine radiography. CT changes associated with otitis media were identical to radiographic changes such as increased soft tissue opacity within the bulla, thickened bulla wall, enlarged bulla, and osteolysis of the bulla wall and trabeculations. The most reliable change on CT images consistent with the correct diagnosis of otitis media appears to be increased soft tissue opacity within the bulla. This finding was present in 93.8% of correctly identified bullae with otitis media. In previous case reports in cattle, increased soft tissue opacity within the bulla also was consistently reported in addition to bulla wall osteolysis and bulla enlargement.[14–17] The thickened bulla wall that often was observed may not have been truly thickened because of the artifact created by fluid that can falsely create the impression of a thickened wall.[18] Regardless, the presence of increased soft tissue opacity within the bulla was sufficient to make a diagnosis of otitis media based solely on this parameter. No false positives were observed with this imaging modality, demonstrating the accuracy of this test.

Table 4. Height, width, and ratios of tympanic bullae measurements on computed tomography images of affected and unaffected bullae with significance $P < .05$.

	Computed Tomography		
	Affected (n = 16)	Unaffected (n = 16)	*P* Value
Height (mm)	20.3	19.2	.16
Width (mm)	28.1	28.1	.98
Height ratio	4.6	4.3	.32
Width ratio	6.3	6.3	.90

When evaluating the images, bulla size was subjectively assessed as enlarged or normal and comparison between sides often was used as a guide. In an attempt to quantitatively determine if affected bullae were significantly larger than unaffected bullae, each bulla was measured on transverse CT images. There was no statistical significance found when evaluating bulla height, width, and calculated ratios between affected and unaffected bullae. No previous study in small animals reports enlarged bulla as an indicator of otitis media, and the only case report in cattle quantitatively describes enlarged bulla.[14] Therefore, bulla enlargement appears subjective depending on the evaluator and is not considered a good parameter to determine the presence of otitis media. Of the 10 calves with otitis media, 4 (40%) were affected unilaterally on the left side. Interestingly, a previous report also indicated a high frequency of otitis on the left side.[19] When reviewing radiographic and CT images, and despite adequate positioning, the position of left and right normal bullae was not always equal. Infrequently, 1 bulla was found to be more cranial than the other by several millimeters. This finding of unequal bullae also has been reported previously[2] but an underlying cause for this possible predisposition to the left bulla has not been identified.

The κ coefficient of 0.94 between CT and necropsy indicates almost perfect correlation. This finding supports the hypothesis that CT is a sensitive imaging modality that can be used as the gold standard for diagnosis of otitis media.

One of the limits of this study is that only 1 board-certified radiologist evaluated the images. Ideally,

numerous radiologists would have assessed the images and the interobserver agreement would have been calculated among evaluators to better determine the diagnostic yield of each modality. Another limitation of this study was the delay between imaging and necropsy. Half of the animals were necropsied within 24 hours of diagnostic tests; however, some animals had a substantial delay of greater than 48 hours before necropsy. One calf was identified as unilaterally affected on both radiography and CT at the time of diagnostic testing but was found to be affected bilaterally at the time of necropsy. In this calf, there was a delay of 5 days between diagnostic imaging and necropsy, which may explain the discrepancy. The calf may have developed otitis media on the other side during this lag period. However, because there was only 1 discrepancy between necropsy and CT, the lag period did not appear to substantially affect results. In addition, the only animal necropsied at 14 days after diagnostic imaging was affected bilaterally and was correctly identified by both radiography and CT. Despite this long delay, the results were not affected, but ideally all animals would have been necropsied within 24 hours of diagnostic imaging.

In conclusion, CT is a valuable diagnostic imaging modality in the diagnosis of otitis media in the calf that is fast, technically easy, and specific. Unfortunately, because of the associated costs, this imaging technology currently is limited to referral practices or universities. As in previous reports in small animals,[13] this study demonstrates CT is more sensitive in the diagnosis of otitis media. In addition, CT is more specific than radiography, which is in contrast to previous reports in which the specificity of CT was slightly less than that of radiography.[10,12] Based on the results of the present study, routine radiography is neither specific nor sensitive and is not a valuable tool in the diagnosis of otitis media in calves. CT has been reported in the diagnosis of otitis media in a few cases in calves, but the diagnosis was not confirmed in all cases.[14–17] Ours is the first prospective study comparing both imaging modalities with postmortem diagnosis. In addition, ours is the first report describing imaging abnormalities in a large number of affected animals in which the diagnosis was confirmed. CT could be used as the gold standard in the diagnosis of otitis media in calves given the results demonstrated in this report. With increasing availability, CT may be utilized more frequently in the diagnosis of otitis media and could replace necropsy as the gold standard in future research studies.

Footnotes

[a] Xylazine, Bayer Inc, Toronto, ON, Canada
[b] Agfa DX-S; Gevaert, Mortsel, Belgium
[c] GE Hi-speed ZXli GE Healthcare; Mississauga, ON, Canada
[d] Euthanasol Schering Canada Inc, Pointe-Claire, QC, Canada
[e] IMPAX 6.0; Agfa, Toronto, ON, Canada
[f] SAS System version 9.1; SAS Institute Inc, Cary, NC

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